Reflective Pavements and the Urban Heat Island Effect

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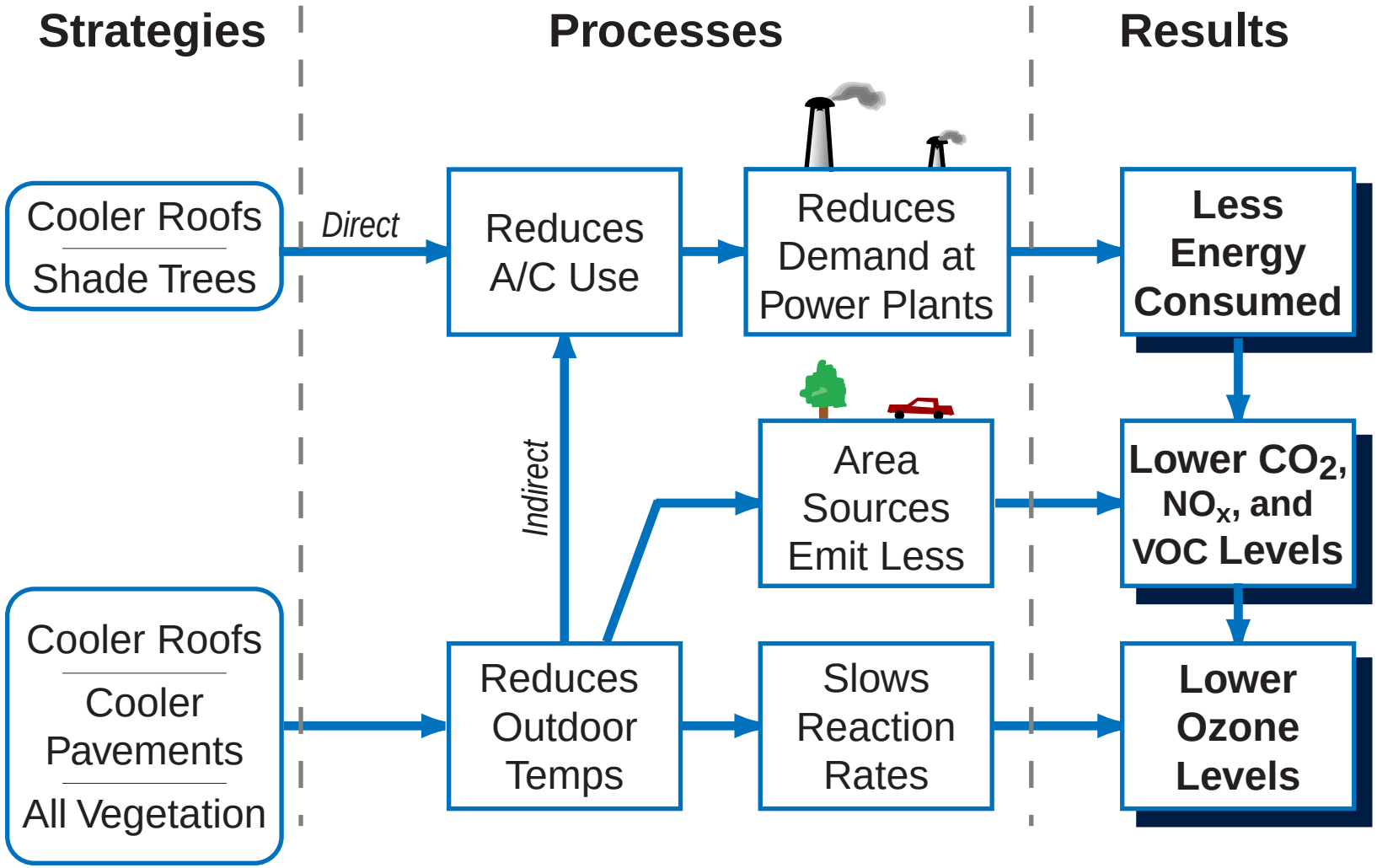
Energy and Air Quality Analysis

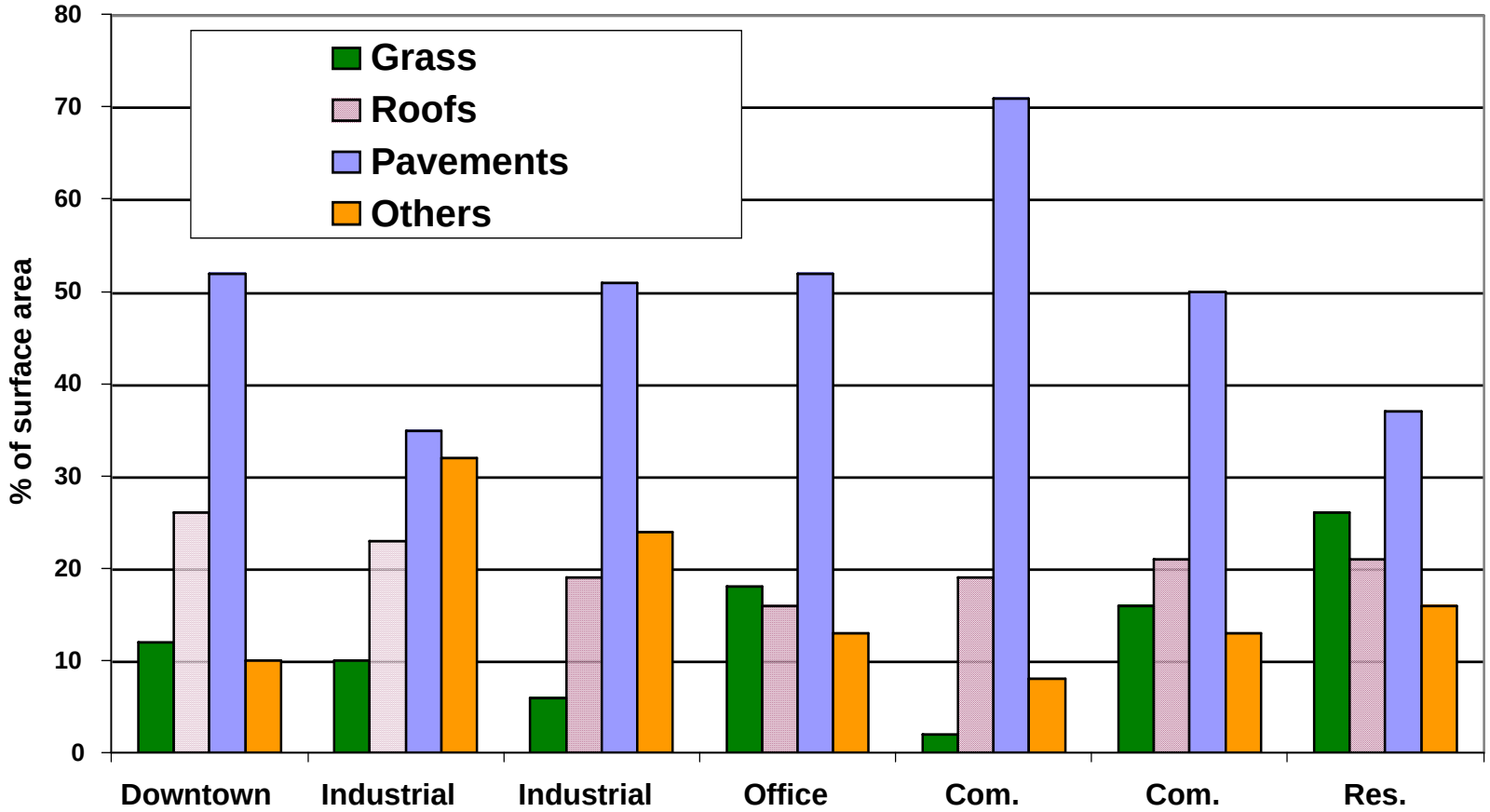


Aerial View of Washington, D. C.

Pavement Area is Substantial

Land Cover in Sacramento, Ca

Pavement Area > 40%



Reflective Pavements are Cooler

Fresh asphalt
Albedo: 0.05
Temperature: 123°F

Aged asphalt
Albedo: 0.15
Temperature: 115°F

Prototype asphalt coating
Albedo: 0.51
Temperature: 88°F

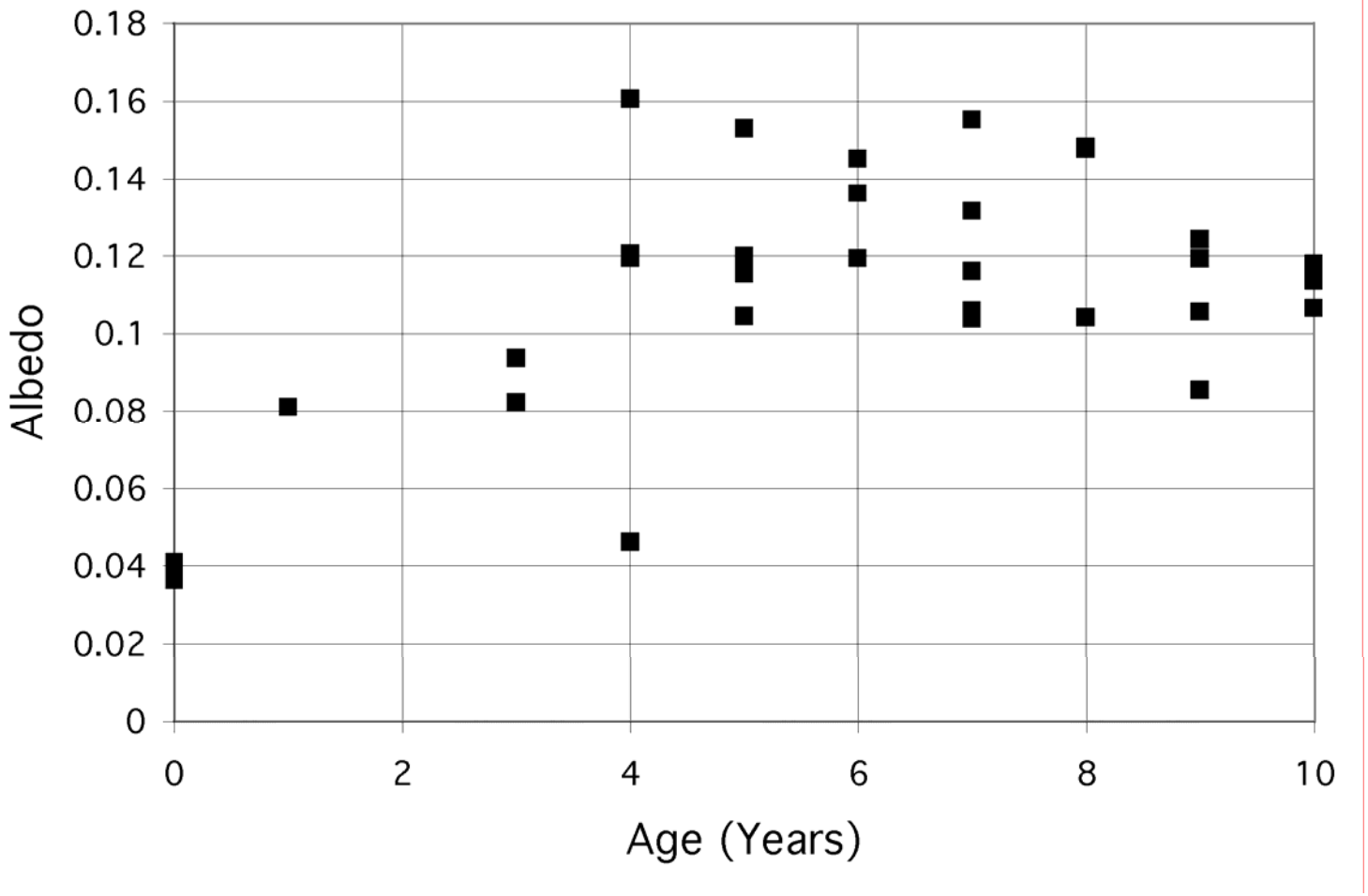
An Approximate Formula for the Change in the Daily (High - Low) Temperature

$$\Delta(T_H - T_L) / (T_H - T_L) \approx ([\alpha_l - \alpha_h] / \alpha_{av}) (A_p / A_{total})$$

$(T_H - T_L)$ = daily (high temperature – low temperature) , say 25° F;
α_h = original higher pavement *absorptance* , say 0.9;
α_l = lower *absorptance* of the changed pavement, say 0.7;
α_{av} = average *absorptance* of the whole city, say 0.8;
A_p = area of the pavements
A_{total} = total area of the city, say $A_p / A_{total} = 0.3$.

Change in temperature rise is ≈ - 2 °F (–1 °C).

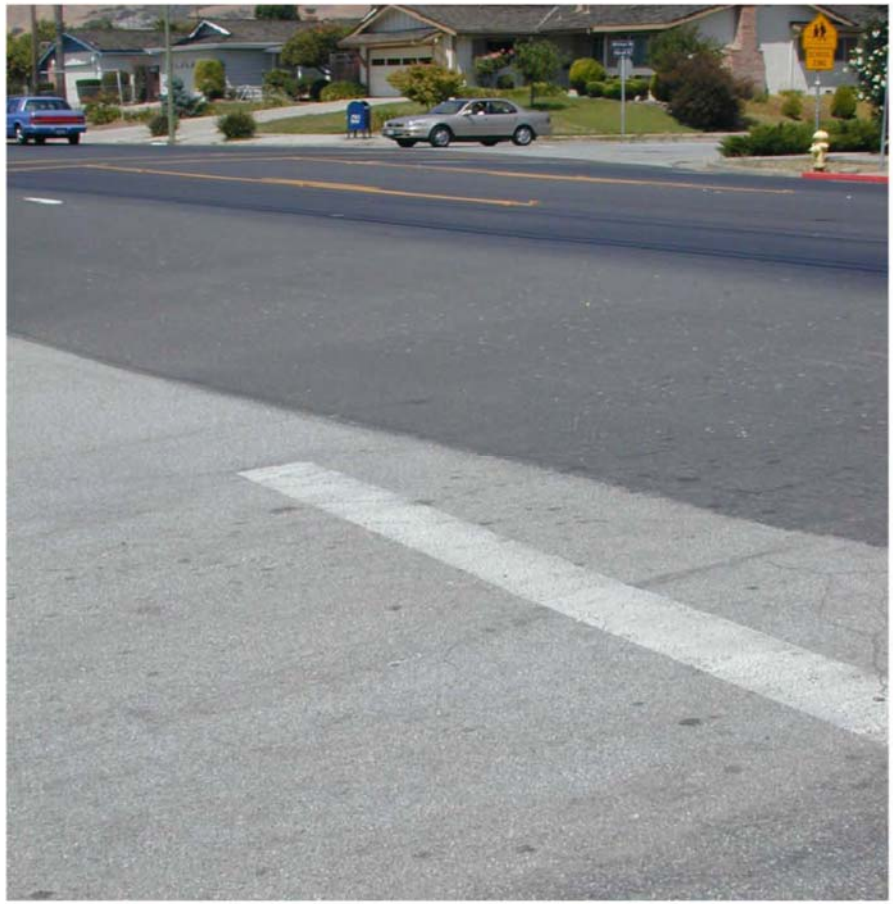
Albedos of Asphalt Concrete Pavements vs. Age



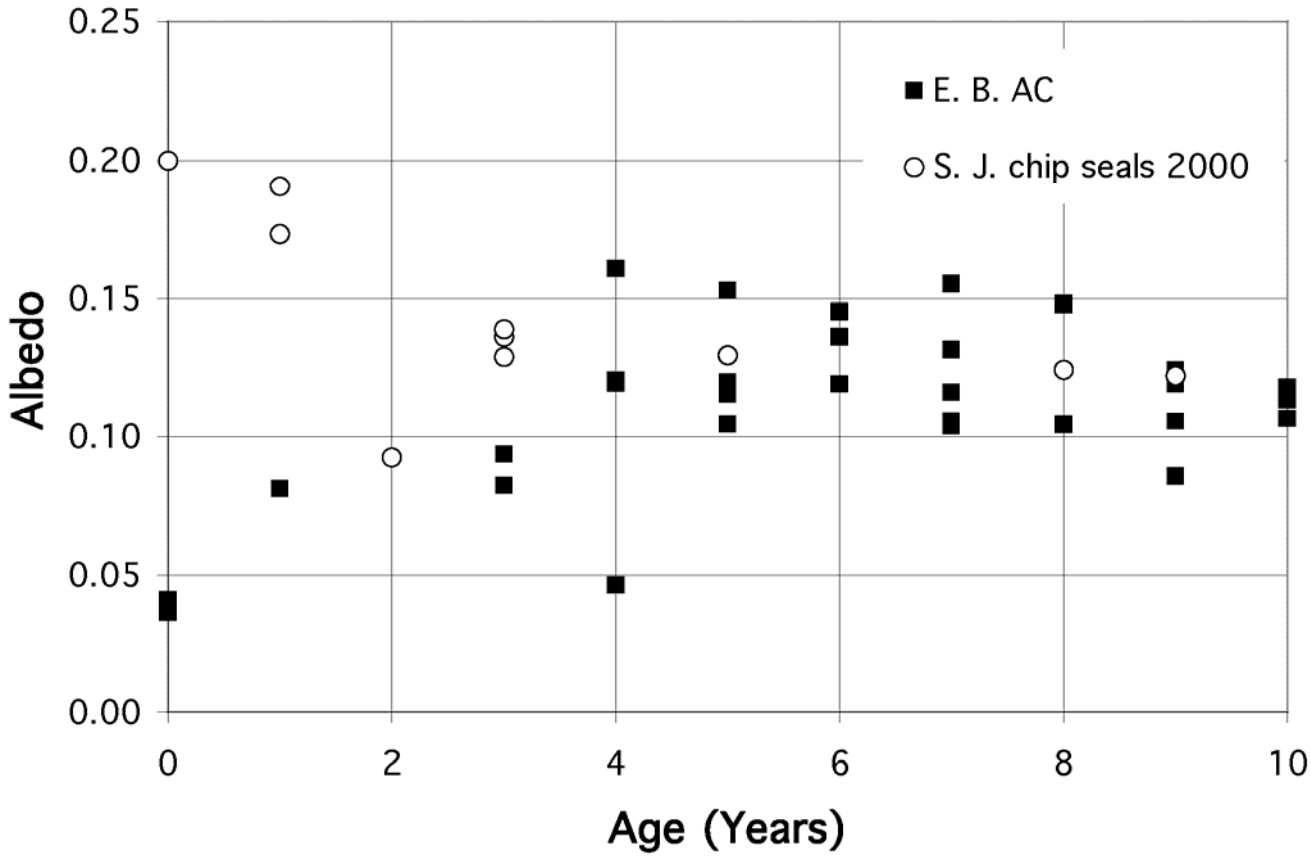
Placing Chip Seals

Source: Asphalt Handbook

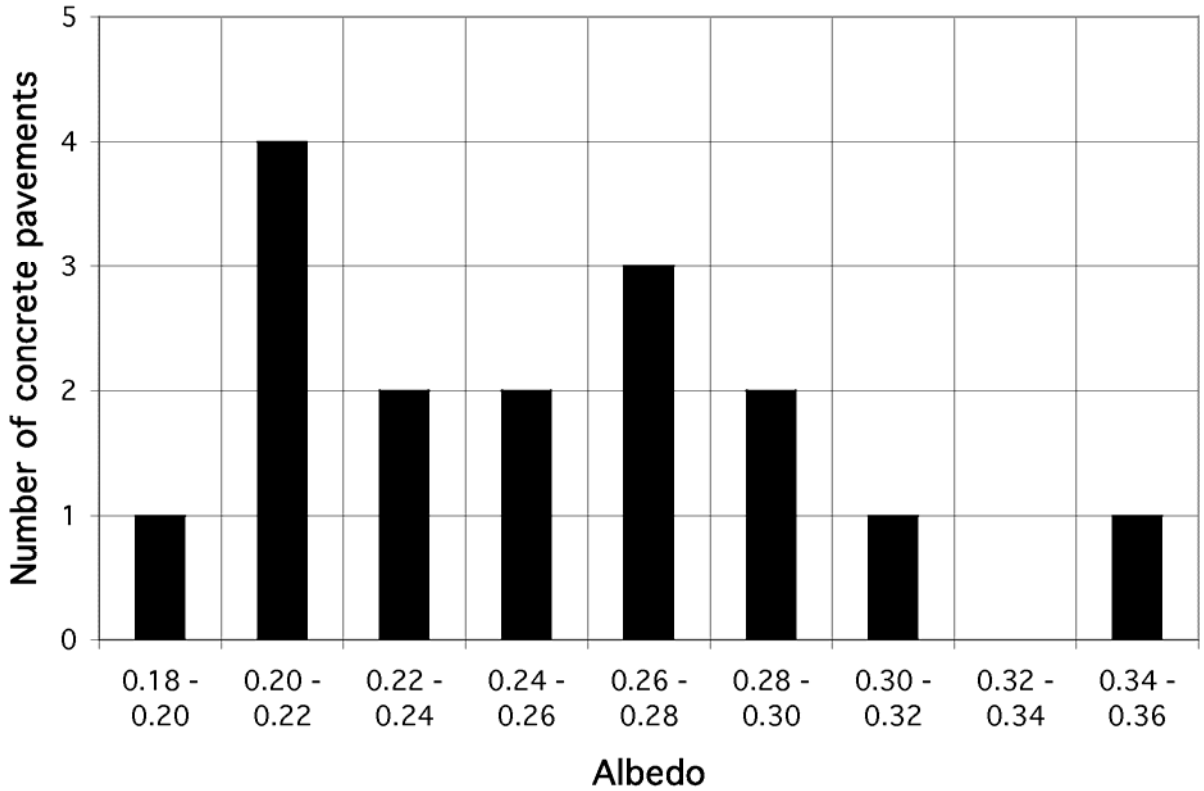
Chip Seal and Asphalt Pavement in San Jose,CA



Albedos of Chip Seals and Asphalt Concrete *vs.* Age



Number of Cement Concrete Pavements vs. Albedo

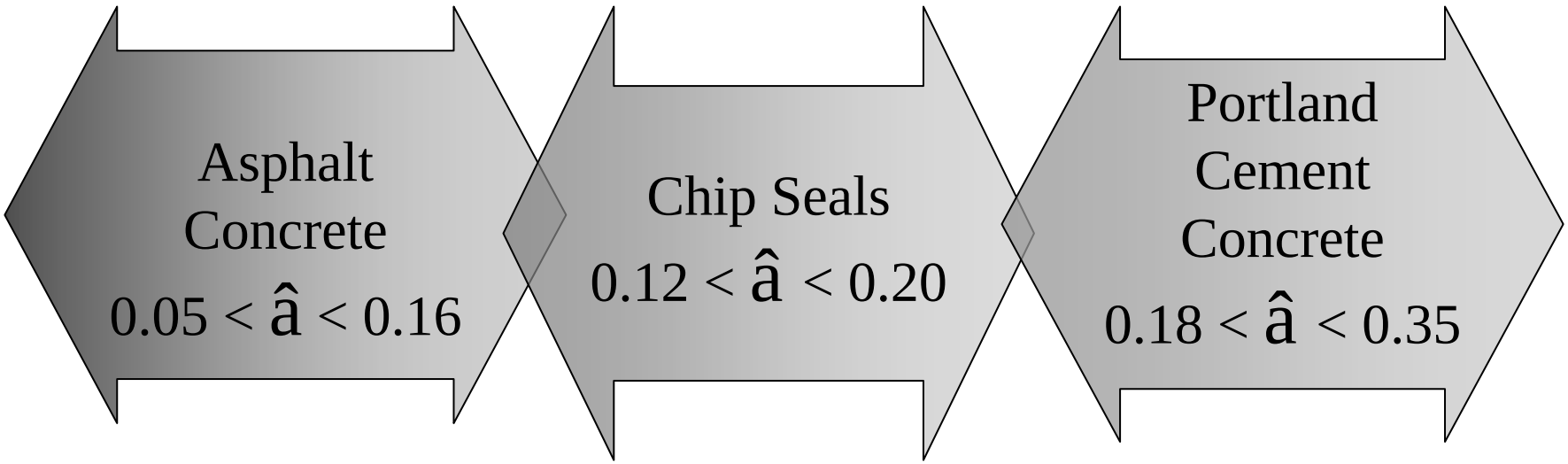


Lab Study of Concrete Albedo

Concrete	**(a)** Unexposed	**(b)** Weathered	**(c)** Weathered, wetted	**(d)** Soiled	**(e)** Abraded	**(f)** Formed
C1:S1:R2 gray cement/ riverbed sand/ granite rock	 ρ=0.44	 ρ=0.34	 ρ=0.14	 ρ=0.43	 ρ=0.24	 ρ=0.25

- 32 varieties of concrete
- Simulated weathering, rain, soiling, abrasion
- Cement albedo has disproportionally strong influence on concrete albedo
- Weather, soiling, abrasion each usually reduced albedo
- Albedo increased as concrete cured (first 6 weeks)

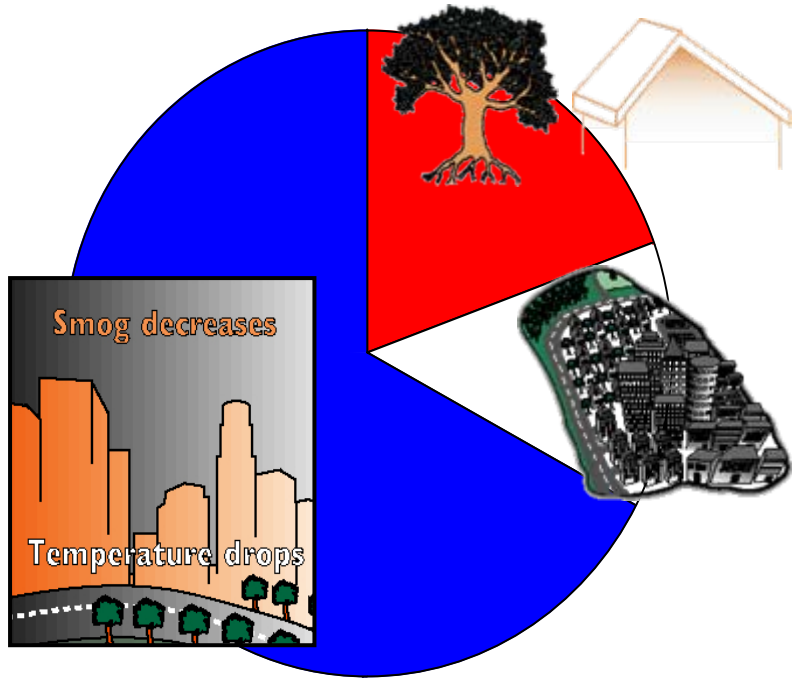
Albedos of Various Pavements We Measured



Potential $ Savings in Los Angeles, CA For Both Direct and Indirect Effects

$ Savings for Los Angeles

- Energy, Direct, $100M/year
- Energy, Indirect, $70M/year
  pavement about $15M/yr.
- Smog, $360M/year
  pavement about $76M/yr.



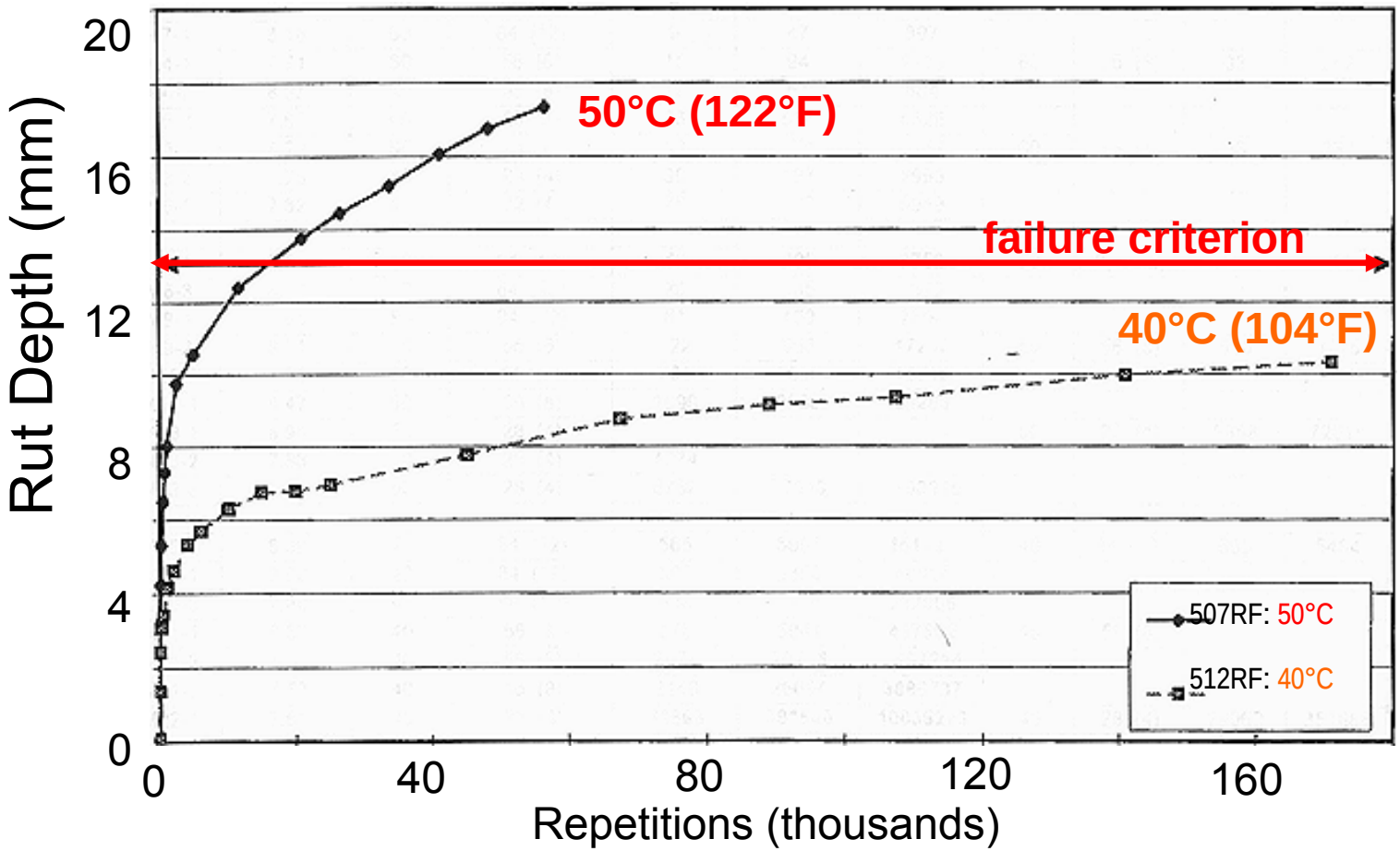
Each city is different, but estimate of national savings: $5B/year

pavement about $0.5B/yr

Collateral Effects of Cooler Pavements

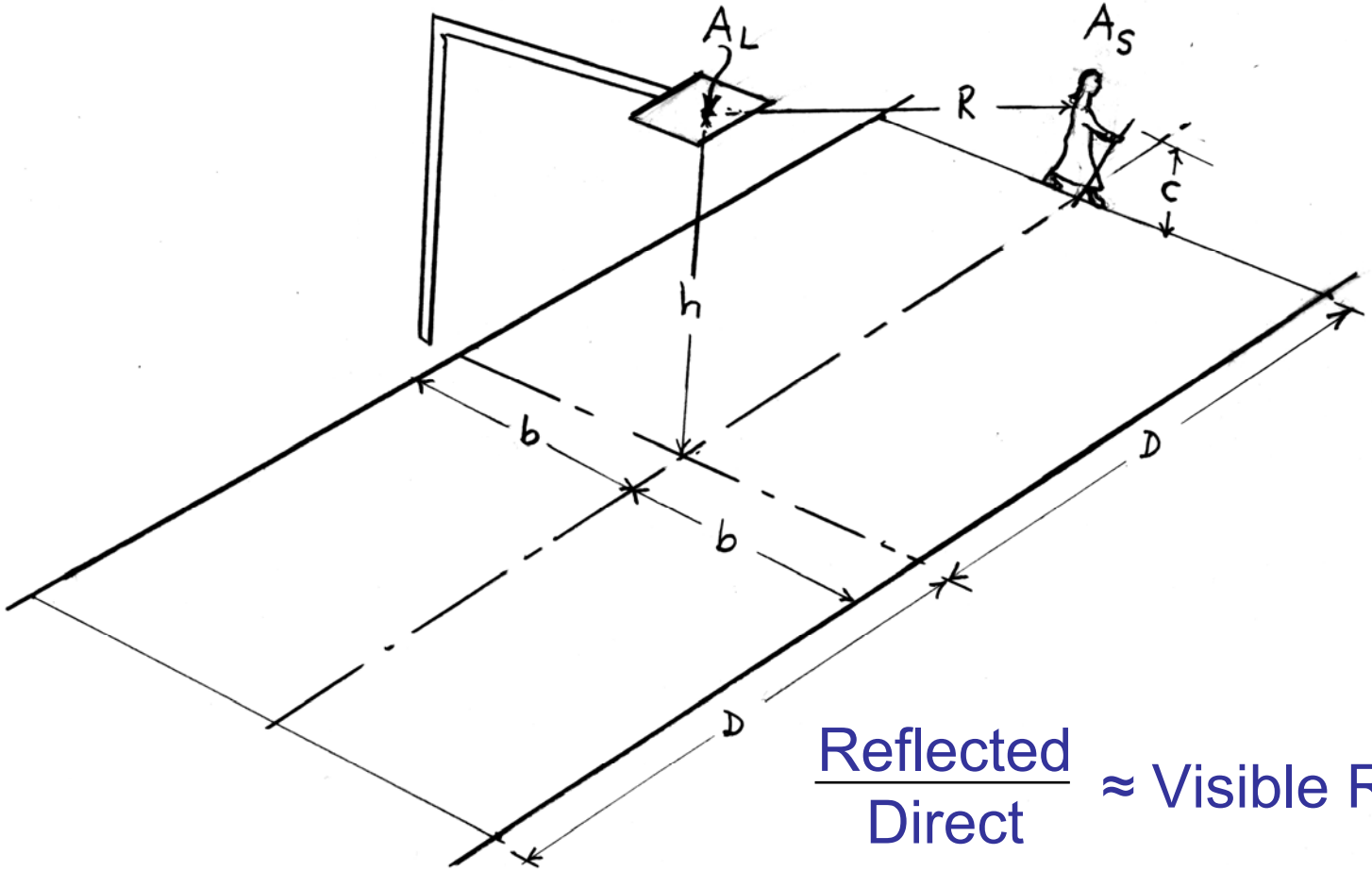
- **Pavement durability**
  For asphalt concrete in hot climates, cooler pavement temperatures → longer pavement life
- **Illumination**
  Roads that reflect visible light illuminate people, objects, signs
- **Glare**
  Not a problem for recommended reflectivities

Temperature Effect on Rutting



Source: Dr. John Harvey, UC B Civil Engineering, Inst. Transportation Studies

Contribution of Pavement Reflectivity to Illumination



$$\frac{\text{Reflected}}{\text{Direct}} \approx \text{Visible Reflectivity}$$

Conclusions about Reflective Pavements

- There are conventional pavements that cover the range of albedos 0.04 to 0.35.
  - *thin*: chip seals, asphacolor, [asphalt]; white PCC topping
  - *thick*: PCC
- The albedos vary over the pavements' lifetimes, but net benefit is possible.
- Benefits include air quality, energy, durability of asphalt concrete, illumination.
- There are experimental reflective pavements:
  - Uncoated chipping with white aggregate [on asphalt]
  - Cool dark dyes [in asphalt]